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Generating pure single-photon states via spontaneous four-wave mixing in a system of coupled microresonators

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Abstract

© 2018 Astro Ltd. We present the optimal design for an on-chip single-photon source based on spontaneous four-wave mixing in a system of coupled ring microresonators, which provides the frequency-uncorrelated joint spectral amplitude of the biphoton field and thereby the generation of pure single-photon heralded states. A simple method is proposed for suppressing negative dispersion effects by optimizing the controlled spectroscopic parameters of the system. It shown that the optimal coupling parameters, in combination with the optimal spectral width of the pump pulse, give rise to the highest purity of the heralded photons for a given pump linewidth.

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Keywords

integrated optics devices, microresonator, quantum information and processing, Single-photon source, spectrum optimization, spontaneous four-wave mixing

References

[1] Eisaman M D, Fan J, Migdall A and Polyakov S V 2011 Invited review article: single-photon sources and detectors Rev. Sci. Instrum. 82 071101

[2] Takeuchi S 2014 Recent progress in single-photon and entangled-photon generation and applications Japan. J. Appl. Phys. 53 030101

[3] Caspani L, Xiong C, Eggleton B J, Bajoni D, Liscidini M, Galli M, Morandotti R and Moss D J 2017 Integrated sources of photon quantum states based on nonlinear optics Light: Sci. Appl. 6 e17100

[4] Politi A, Matthews J C F, Thompson M G and O'Brien J L 2009 Integrated quantum photonics IEEE J. Sel. Top. Quantum Electron. 15 1673-84

[5] Harris N C, Grassani D, Simbula A, Pant M, Galli M, Baehr-Jones T, Hochberg M, Englund D, Bajoni D and Galland C 2014 Integrated source of spectrally filtered correlated photons for large-scale quantum photonic systems Phys. Rev. X 4 041047

[6] Turner A C, Foster M A, Gaeta A L and Lipson M 2008 Ultra-low power parametric frequency conversion in a silicon microring resonator Opt. Express 16 4881-7

[7] Azzini S, Grassani D, Strain M J, Sorel M, Helt L G, Sipe J E, Liscidini M, Galli M and Bajoni D 2012 Ultra-low power generation of twin photons in a compact silicon ring resonator Opt. Express 20 23100-7

[8] Savanier M, Kumar R and Mookherjea S 2016 Photon pair generation from compact silicon microring resonators using microwatt-level pump powers Opt. Express 24 3313-28

[9] Reimer C et al 2014 Integrated frequency comb source of heralded single photons Opt. Express 22 6535-46

[10] Collins M J et al 2013 Integrated spatial multiplexing of heralded single-photon sources Nat. Commun. 4 2582

[11] Heuck M, Pant M and Englund D R 2018 Temporally and spectrally multiplexed single photon source using quantum feedback control for scalable photonic quantum technologies New J. Phys. 20 063046

[12] Christ A and Silberhorn C 2012 Limits on the deterministic creation of pure single-photon states using parametric down-conversion Phys. Rev. A 85 480

[13] Helt L G, Yang Z, Liscidini M and Sipe J E 2010 Spontaneous four-wave mixing in microring resonators Opt. Lett. 35 3006-8

[14] Vernon Z et al 2017 Truly unentangled photon pairs without spectral filtering Opt. Lett. 42 3638-41

[15] Kok P 2016 Photonic quantum information processing Contemp. Phys. 57 526-44

[16] U'Ren A B, Silberhorn C, Banaszek K, Walmsley I A, Erdmann R, Grice W P and Raymer M G 2005 Generation of pure-state single-photon wavepackets by conditional preparation based on spontaneous parametric downconversion Laser Phys. 15 146

[17] Walls D F and Milburn G J 2008 Quantum Optics (Berlin: Springer)

[18] Chen J, Levine Z H, Fan J and Migdall A L 2011 Frequency-bin entangled comb of photon pairs from a silicon-o--insulator micro-resonator Opt. Express 19 1470-83

[19] Helt L G, Liscidini M and Sipe J E 2012 How does it scale? Comparing quantum and classical nonlinear optical processes in integrated devices J. Opt. Soc. Am. B 29 2199-212

[20] Camacho R M 2012 Entangled photon generation using four-wave mixing in azimuthally symmetric microresonators Opt. Express 20 21977-91

[21] Vernon Z and Sipe J E 2015 Strongly driven nonlinear quantum optics in microring resonators Phys. Rev. A 92 033840

[22] Vernon Z and Sipe J E 2015 Spontaneous four-wave mixing in lossy microring resonators Phys. Rev. A 91 053802

[23] Vernon Z, Liscidini M and Sipe J E 2016 No free lunch: the trade-off between heralding rate and efficiency in microresonator-based heralded single photon sources Opt. Lett. 41 788-91

[24] Garay-Palmett K, U'Ren A B and Rangel-Rojo R 2010 Conversion efficiency in the process of copolarized spontaneous four-wave mixing Phys. Rev. A 82 043809

[25] Garay-Palmett K, Jerónimo-Moreno Y and U'Ren A B 2012 Theory of cavity-enhanced spontaneous four wave mixing Laser Phys. 23 015201

[26] Chuprina I N, An P P, Zubkova E G, Kovalyuk V V, Kalachev A A and Gol'tsman G N 2017 Optimisation of spontaneous four-wave mixing in a ring microcavity Quantum Electron. 47 887

[27] Law C K, Walmsley I A and Eberly J H 2000 Continuous frequency entanglement: effective finite Hilbert space and entropy control Phys. Rev. Lett. 84 5304-7

[28] Fedorov M V and Miklin N I 2014 Schmidt modes and entanglement Contemp. Phys. 55 94-109

[29] Law C K and Eberly J H 2004 Analysis and interpretation of high transverse entanglement in optical parametric down conversion Phys. Rev. Lett. 92 127903

[30] Fedorov M V, Efremov M A, Volkov P A and Eberly J H 2006 Short-pulse or strong-field breakup processes: a route to study entangled wave packets J. Phys. B: At. Mol. Opt. Phys. 39 S467-83